VOLUME XXX NUMBER 8 WHOLE NUMBER 257

THE JOURNAL

OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(*Ten numbers per year*)

October, 1936

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

Vol. XXX, No. 8 OCTOBER, 1936 Whole No. 257

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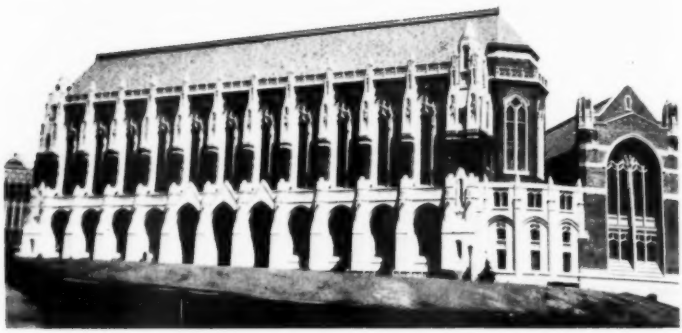
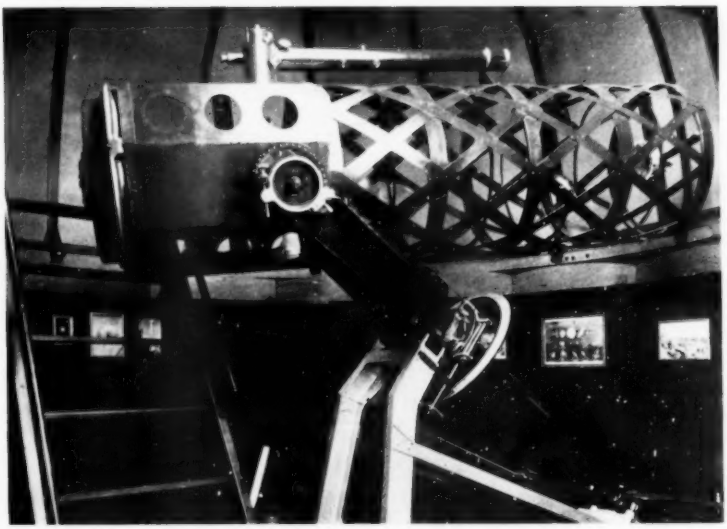


A Portion of the Library, University of Washington.

PLATE XXIV



A View of the 22-inch Reflecting Telescope recently constructed by G. F. Tauchmann of Berkeley, California.

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Vol. XXX, No. 8 OCTOBER, 1936 WHOLE NO. 257

THE RECENT ANNUAL MEETING OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC

By ANDREW McKELLAR

(With Plates XXIII, XXIV)

THE annual meeting for 1936 of the Astronomical Society of the Pacific was held in conjunction with meetings of the Pacific Division of the American Association for the Advancement of Science. From June 16 to 20 the University of Washington in Seattle, which is celebrating the seventy-fifth year of its founding, assumed the role of host to the scientists. This institution of learning is now among the largest in the west and its majestic Tudor Gothic buildings and beautiful campus provided an ideal setting for the meetings.

The first papers were presented on Tuesday, June 16. Inasmuch as the primary purpose of scientific meetings is usually considered to be the reading of papers giving results of researches in the various branches of science, it would seem appropriate to mention here some of the interesting astronomical ones. Tuesday was devoted to a number of so-called "Research Announcements". These addresses were in the nature of critical surveys reviewing recent advances in certain selected fields of scientific endeavour. Astronomy was represented by Dr. W. E. Harper, director of the Dominion Astrophysical Observatory, who gave an address on "Stellar Spectroscopy". He mentioned the several new large telescopes lately completed or under construction, the recently developed aluminizing process for coating telescope mirrors and the resultant increase in our knowledge of ultra-violet stellar spectra, and the improvements in photographic emulsions that have made possible the extension of our knowledge

of stellar spectra in the far infra-red region. He also discussed the stellar radial velocity programmes of the various observatories, the uses made of the radial velocities in obtaining data on binary star orbits, on galactic rotation, etc., before turning to more highly specialized topics of stellar spectroscopy.

The first session of regular papers was begun at 9.30 a.m. on Wednesday, June 20. Among the papers was one by Dr. J. H. Moore of the Lick Observatory giving all the statistical data on spectroscopic binaries compiled in the preparation of the "Fourth Catalogue of Spectroscopic Binaries", which is now in process of publication. He made it clear that for many years to come there will be no lack of material for the person interested in calculating binary orbits. An amateur astronomer, Mr. G. F. Tauchmann of Berkeley, California, described the construction of a "homemade" 22-inch reflecting telescope. In speaking of his work, which has since been fully described in the June number of the Publications of the Astronomical Society of the Pacific, Mr. Tauchmann stressed the ambition and endurance necessary for success. The opinion held by a great many astronomers that the solar spectrograms taken by Rowland about forty years ago have not since been equalled or surpassed in quality was shown to be erroneous by Dr. H. D. Babcock of Mount Wilson Observatory. Dr. Babcock exhibited actual prints of some of Rowland's best plates and prints of spectrograms of the same dispersion recently obtained at Mount Wilson. The much superior resolving power of the latter was clearly and convincingly evident.

A joint session with the American Physical Society took place on Wednesday afternoon, when two invited papers were presented. The first of these dealt with recent cosmic ray studies and was given by Dr. Carl Anderson of the California Institute of Technology. The second, on galactic rotation, was delivered by Dr. J. A. Pearce of the Dominion Astrophysical Observatory. Both were excellent summaries of the work done and our present knowledge of these two important fields of research.

This was the biggest "Astronomical Day" of the meetings in Seattle, for the popular lecture in the evening, to which those in all the affiliated scientific societies were invited, was upon an astronomical subject. It was given by Professor R. C. Tolman of the

California Institute of Technology, President of the Pacific Division of the A.A.A.S., and was entitled "The Present Status of Cosmology". In a most interesting and masterful fashion the growth, from earliest times, of man's ideas concerning the universe was outlined. Finally our present conceptions, taking into consideration all observational features, such as, for example, the recession of the extra-galactic nebulae, were sketched. The slides illustrating the lecture were exceptionally good.

The last session at the University of Washington took place on Thursday morning. A paper by R. S. Richardson of Mount Wilson described the coincidence of bright hydrogen eruptions from the solar surface and terrestrial radio fade-outs. He dealt particularly with one that occurred on April 1, 1936, although on several dates similar phenomena took place. In each case there occurred simultaneously a solar eruption, a disturbance in the earth's magnetic field and a fade-out in radio transmission in certain wave-length bands. Another interesting paper was that of Dr. E. C. Slipher of the Lowell Observatory on observations of the planets. He had taken direct photographs of the planets using various different colour filters and from the different photographs, complete coloured reproductions of the planets could be assembled. Slides of such reproductions were shown, those of Mars and Jupiter being particularly striking. The snow-cap of Mars was white, the temperate zones greenish in colour and the equatorial regions brown, a colour not unlike our own sandy deserts. In the bands on Jupiter were shown white cloud-like formations.

At the end of an afternoon free from the fetters of "papers", the astronomers met at the Edmond Meany Hotel for the dinner of the Astronomical Society of the Pacific. Dr. R. H. Trumpler acted as master of ceremonies and the occasion was a most enjoyable one. After dinner one eminent astronomer, who had apparently been expending considerable critical thought on the question of the most desirable features of scientific meetings, was moved to arise and propose that at the next meetings of the society no time be allotted for the formal presentation of papers, thus leaving the full time available for dinners and informal discussion. Although no definite action was taken on this proposal it quite evidently did not meet with

complete disapproval. Dr. Babcock was called upon and in an interesting and informative manner discussed the ruling and performance of diffraction gratings.

All the members of the Astronomical Society of the Pacific and of the A.A.A.S. were invited to visit the Dominion Astrophysical Observatory in Victoria, B.C., for the final meeting of the former society. Leaving Seattle by C.P.R. steamer early on the morning of Friday, June 19, about twenty scientists, most of them astronomers, arrived in Victoria in the early afternoon. Others brought their own cars by the ferry route. Their arrival was most auspiciously heralded, for on the previous night not only was there an exceptionally fine auroral display but there appeared a third magnitude nova in the north-east sky. The nova was discovered independently by Peltier and others and has subsequently been found to be just within the border of the constellation Lacerta. The visitors were also greeted by ideal weather, well nigh perfect from the standpoint of both excursionists and astronomers.

The scientists were driven to the observatory where they assembled at 3.30 p.m. for the final session of papers, one by each member of the observatory staff. A number of members of the local centre of the R.A.S.C. availed themselves of the invitation to attend the meeting. Professor R. C. Tolman presided and Dr. Harper, who opened the meeting, welcomed the visiting scientists, briefly sketched the history of the Dominion Astrophysical Observatory and made reference to his present work on spectroscopic binary orbits. Dr. Pearce next gave data on new orbits of three massive eclipsing binary star systems, showing that one orbit had unquestionably changed its orientation in space during the last 20 years. Dr. Beals spoke on the nature of interstellar lines, giving observational material which tended to prove the existence of random motions in the great clouds of interstellar matter. Dr. Petrie outlined a method of determining from the photometric study of spectrum lines the relative brightness of the two stars comprising a spectroscopic binary star and showed that satisfactory results had been obtained for a number of eclipsing binaries. Dr. McKellar presented results on the measurement of the relative intensities of bands due to the two isotopic forms of carbon in the atmospheres of certain stars. These results

indicated that in the most reliably determined case the relative abundance of the two kinds of carbon atoms in the star was not radically different from that in samples of terrestrial carbon, contrary to what had been heretofore supposed, but was of the same order of magnitude as that which is found in carbon on our earth. Dr. Petrie, upon having received notice the previous night of the discovery of Nova Lacertae, obtained a number of spectrograms of the object. He showed and discussed some slides he had made of the spectra. The displacement of the spectral lines on the plates taken the night of June 18 indicated that a shell of gas was being ejected from the star with a velocity of about 1,100 kilometres per second.

After the meeting, bountiful refreshments were served to those present. Thus fortified, they displayed their abilities on the putting green around the observatory, inspected the laboratory equipment and explored the Hill until dusk, when all foregathered at the dome. There Dr. Pease of the Mount Wilson Observatory presented a very interesting address on the history to date of the 200-inch telescope. About a hundred slides were used to illustrate the various phases of the great project. The very successful meeting was brought to a close by a session with the 72-inch telescope at which, under the guidance of Dr. Pearce, the visitors viewed a number of astronomical objects.

Victoria, B.C.

APPLIED SPECTROSCOPY*

By H. J. C. Ireton

SINCE the beginning of the twentieth century, the emphasis has been on the structure of spectral lines rather than on spectrum analysis and only within the past few years has there been any considerable further progress in the latter subject. These recent developments concern both the qualitative and the quantitative sides of the subject, and have as their prime object the rendering of the subject of increased value to science and industry.

Qualitative Spectrum Analysis

Under this head there are two broad types of problem which may be solved by the spectrograph—

(1) Does a substance contain a given metal?

(2) What are the metals present in a given substance?

We shall consider a typical procedure in each case.

(1) To ascertain whether a substance contains a specified metal, three spectra are taken: the first is that of any metal which is known to be present, or if none such be known then one of the purest iron obtainable; the second, that of the sample under test; while the third is that of the metal whose presence or absence is to be determined. A comparison of these spectra will usually supply an answer to the question.

(2) To determine all the metals present in a specimen. By using a comparison spectrum as in (1) of the particular element in question the determination of wave-lengths is entirely obviated. It is not necessary, however, to have a complete comparison spectrum of an element in order to identify it in a sample. Recently Ryde and Jenkins at the Research Laboratories of the General Electric Co. Ltd. at Wembley, England, have developed a "Raies Ultimes" powder. It consists of small quantities of fifty elements incorporated in a base material composed of zinc, magnesium and calcium oxides. The

*A portion of a lecture before the R.A.S.C. at Toronto, March 3, 1936, with lantern illustrations.

quantity of each element has been so adjusted that only the most easily excited lines (*raies ultimes*) and the most important sensitive lines appear when the spectrum is excited by placing some of the powder on the lower (positive) pole of an arc between graphite electrodes.

When used as a comparison spectrum the sensitive lines of all the elements present as impurities in the substance under examination coincide with the corresponding lines in the "R.U." spectrum. The elements present in the sample can be identified from a set of enlargements of the arc spectrum of the "R.U." powder. It should be noted that in every spectrum there are groups of lines which are highly characteristic of the metal, and these become familiar and recognizable at a glance by those making frequent use of the spectrograph.

Qualitative Spectrum Analysis

In recent years quantitative spectrographic measurements have become a matter of routine in many laboratories. They have been found to be peculiarly suited to a type of analysis which is both tedious and uncertain when attempted by chemical operations—the determination of constituents present in small quantity.

A procedure which until recently found the most extended use was developed by A. de Gramont and by many other workers, *e.g.*, Meggers, Kiess and Stimson at the Bureau of Standards. The principle utilized is the comparison of the intensity of the lines of an element as registered on a spectrogram from a sample, with those of the same lines appearing on spectrograms taken from standard specimens of known composition. The comparison is made by visual inspection of a series of photographs, and with the help of a well chosen series of standards the results are of considerable accuracy.

Another method, which combines convenience and accuracy, is the Logarithmic Sector method. In this instrument is a metal disc, the periphery of which is cut into the shape of a logarithmic spiral. It is rotated in front of the slit, and if the shape of the spiral is properly selected the effect is to produce on the plate spectrum lines, the differences in the lengths of which are in proportion to the logarithms of the relative intensities of the corresponding radiations.

Of late years the microphotometer has been used as an adjunct to spectrum analysis. It consists of a photoelectric or thermoelectric device for measuring the blackening of a photographic plate.

There are other accepted methods of quantitative analysis but those described are typical and of general application.

With the help of the new methods that have been opened up by the spectrograph in the domain of qualitative and quantitative chemical analysis it has become possible to apply spectrum analysis to biological problems. Among these are to be included all the questions arising in theoretical and practical medicine regarding the metabolism of the heavy metals and its significance for the organism, whether sound or diseased; or the treatment of disease by the administration of heavy metals; or the branches of forensic medicine in connection with cases of poisoning or of shot wounds, also electropathology and industrial hygiene. The work of Walther and Werner Gerlach and others in the above fields is worthy of special mention.

In one criminal investigation the spectrographic analysis of a smear on a coat was identified with the putty rubbed from a window during a burglary. In another case telephone wire stolen from a government department was identified spectroscopically as containing traces of certain ingredients present in government stock but not in samples obtained locally.

Industrial and Scientific Applications of Emission Spectrum Analysis

There are few branches of either science or industry founded on the properties of materials which are not illumined by the application of spectroscopic analysis. Metals, minerals, chemicals, vegetable tissues and animal substances are all explorable by emission spectroscopy.

The examination of a metal by spectroscopy will show many impurities not discoverable by chemical means. This is also true in the analysis of natural water. In the course of the inquiry into the "Mineral Constituents of Tinctures and Drugs" by Judd Lewis the spectroscope revealed the universal distribution of boron over a wide range of substances examined. The majority of natural waters contain traces of this element, whence it was assumed that it is

through water supplies that boron is so widely distributed in the vegetable kingdom.

The contamination of foods, beverages and the like is a constant source of anxiety to the manufacturer. Traces of contaminating metals from the plant or containers are readily revealed by the spectrograph.

Working spectroscopically in the ash of blood and milk much information has been gained concerning the assimilation of aluminium by the human system.

To students of the history of art exact knowledge of materials used by ancient craftsmen is of importance and in researches of this kind the spectroscope has been of great assistance. Similar illumination has been cast on the authenticity of paintings by the spectroscopic study of the elements in their pigments.

A different kind of research is a study of spectrograms of dirt from roofs on the outskirts of London, England, and the fuel used in the building. The spectra give data of significance to those interested in atmospheric purity and allied problems.

Another interesting application has to do with the purity of milk. All natural waters contain dissolved salts. Both milk and water contain small quantities of lead and the amount is greater in water. Spectrographic analysis is sensitive enough to show this clearly and it becomes interesting if the spectrum of a specimen of milk departs from the normal in the direction of the local water supply.

In this summary no mention has been made of absorption spectroscopy. We have seen that by measuring the lines in an unknown spectrum we can determine the elements composing the substance excited to give an emission spectrum. In a similar fashion a curve showing the proportion of light of every wave-length absorbed by a given substance in the natural state or in solution identifies the substance. It matters not whether the substance is elemental or compound, whether inorganic or organic.

The field of industrial application includes the dyes, rare earths, vitamins, alkaloids, blood sera, proteins, glasses of every type, oils, vegetable and animal pigments and many other materials. The observations give information on the chemical constitution of the substance investigated.

Another branch of spectrum analysis has to do with the X-ray spectrum of elements. It has been fundamental in the discovery of new elements and in the determination of the structure of matter. The applications in the single field of practical metallurgy are innumerable.

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THE PHYSICAL STATE OF THE UPPER ATMOSPHERE

By B. HAURWITZ*

FOREWORD

THE following survey of the present knowledge about the upper atmosphere was first presented as a series of eight public lectures which were given in April 1936 under the auspices of the Department of Physics in the University of Toronto. The author wishes to express his gratitude to Prof. Burton, head of the Department of Physics, to Prof. Chant for the editing and the publication of the lectures in this JOURNAL, and to Dr. E. Cohen and Mr. A. Thomson for revising the manuscript.

The figures are mostly taken from other publications. I am indebted to the various authors, institutions and publishing houses for the permission to reproduce the figures, in particular to the Akademische Verlagsgesellschaft in Leipzig for figures 14-17, 19, 20, 27, to the Royal Society of London for figures 2, 4, 23-26, to Verlag J. Springer in Berlin for figures 8-10, to the editor of "Terrestrial Magnetism and Atmospheric Electricity" for figures 6 and 7, and to the editor of the "Review of Modern Physics" for figure 3.

I. INTRODUCTION, TROPOSPHERE AND STRATOSPHERE

We are to-day comparatively well-informed about the mean state of the atmosphere up to about 30 km. Pilot balloons released at the surface of the earth and observed with theodolites give us the wind up to the highest point of observation of the balloon. To measure the temperature and pressure, larger balloons with self-recording instruments are sent up. At great heights, where the inner pressure of the balloon becomes much greater than the exterior pressure of the atmosphere, the balloon bursts and the instrument sinks to the earth, the fall being retarded by a para-

*Carnegie Fellow, Department of Physics, University of Toronto; Research Associate, Blue Hill Observatory, Harvard University.

chute. Balloons have reached heights above 30 km. For daily weather forecasting, however, this method cannot be used since obviously too long a time elapses before the instrument is found and forwarded to the particular meteorological institution which released it. Upper air observations for this type of work are to-day mainly obtained by airplane flights made for this purpose. In the future, radio-meteorographs carried aloft by balloons will probably come into general use.

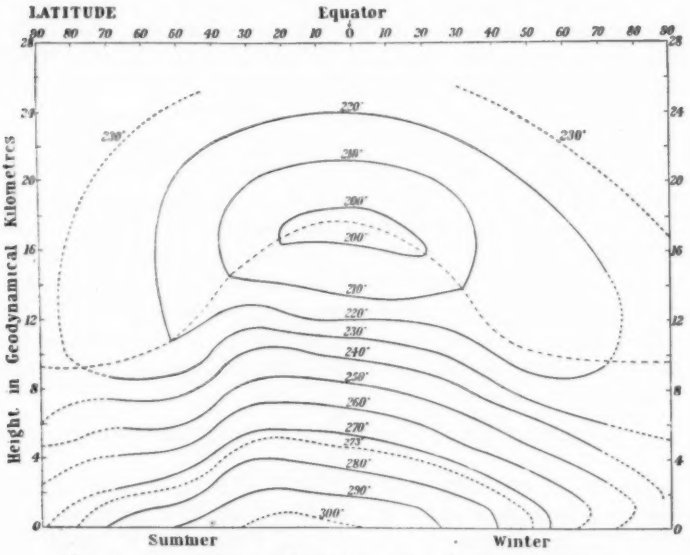

Fig. 1.—Temperature distribution, after Gregg and others.

The variation of temperature with altitude, obtained in such investigations, is summarized in fig. 1[1]. There are of course deviations from this simple picture but these do not concern us here. The figure gives a cross-section through the atmosphere in a meridional direction, the right side showing the surfaces of equal temperature in winter, the left side in summer. It will be seen that the temperature first decreases with the altitude at the rate of about

6°C. per kilometre, except in the polar regions in winter, where a slight increase in temperature is found. In polar and temperate latitudes this regular decrease of the temperature with altitude has been found to extend up to about 10 km.; in tropical regions much higher, near the equator to about 17 or 18 km. This lower layer which has a distinct temperature lapse rate is called the *troposphere*. The clouds which we observe are, with a few exceptions to be mentioned later, phenomena of this layer. Higher up, beyond it, the temperature either increases slightly or remains constant, as is shown in fig. 1 by the greater distance between the isotherms or their vertical position in summer in our latitudes. This upper, practically isothermal, layer is the *stratosphere*. The boundary between troposphere and stratosphere, called the *tropopause*, is indicated in fig. 1 by the broken line which intersects the isotherms. It will be seen that the lower portion of the stratosphere is colder over the equator (around −70°C.) than over the higher latitudes (−50°C.). At higher altitudes in the stratosphere, however, this latitudinal temperature gradient becomes smaller. The theories offered for this division of the lower atmosphere into troposphere and stratosphere and for the isothermal state of the stratosphere, which were critically discussed by Pekeris[2], had to be abandoned after ozone was discovered as a powerful absorber of short-wave radiation in the atmosphere, and at present we do not have a complete theory of the stratosphere based on the latest observational material. (See the chapter on Ozone.)

The distribution of pressure in the vertical direction will be found discussed in every meteorological text-book. It may be mentioned here that at about 6 km. we have less than half of the mass of the atmosphere above us, at 16 km. about one-tenth and at 20 km. only a little more than one-twentieth. Thus the part of the atmosphere which is dealt with here, the upper atmosphere, represents only a small fraction of the total mass.

II. Some Optical Phenomena. Mother-of-Pearl Clouds and Noctilucent Clouds

Attempts have been made to deduce the existence of layers of discontinuity in the upper atmosphere from observations of the

twilight and the colour of the sky at sunset and sunrise. These phenomena are rather indistinct and very difficult to measure with precision, so that definite results cannot be obtained in this way. After great volcanic outbreaks, notably after the outbreak of Krakatoa in 1883, a corona of chestnut-brown colour was observed around the sun in the cloudless sky, the so-called Bishop's ring. While the ordinary coronae around the sun or moon are due to diffraction by water droplets condensed in the atmosphere, this ring was evidently due to volcanic dust in the atmosphere. We do not know the altitude of the dust particles but from the measurements of the angular diameter of the ring the size of the diffracting particles can be computed. Under the assumption that the particles are spherical their radius r is given by

$$2r = \frac{1.22\lambda}{\sin \theta} \qquad (1)$$

In this formula λ is the wave-length of the diffracted light, which we put equal to $.571 \times 10^{-4}$cm., θ the angular distance from the outer edge of the ring to the limb of the sun. For θ, values of about 22°.5 are reported, giving for the diameter of the particles a value of $.184 \times 10^{-3}$cm. If the particles were oblong the factor 1.22 in equation (1) would have to be replaced by 1.00, and the width of the particles would be $.15 \times 10^{-3}$cm. It should be emphasized that these measurements are not very reliable since the determination of the angular diameter of the ring was difficult, owing to its faintness. Values of the diameter about twice as large have been reported, which would reduce the size of the particles to almost half the value given above.

As mentioned in the introduction, most clouds are found in the troposphere. Störmer, however, and, earlier, Mohn, have observed certain clouds in Norway, which according to their measurements appear at heights between 22 and 30 km., while the highest cirrus clouds observed at Oslo reached a height of 11.34 km.[3, 4]. These stratospheric clouds are called *mother-of-pearl* clouds owing to their remarkable play of colour. The colours extend, band after band, into the cloud centre, while in the so-called iridescent clouds, which can be observed quite frequently in the troposphere, the colours are

arranged in fringes around the edges of the cloud. The reader who desires more information about the observation of these clouds is referred to a paper by A. Thomson in this JOURNAL[5]. Here we shall only mention that Störmer on one occasion could observe a corona around the moon with an inner diameter of 14° to 15° through a mother-of-pearl cloud. If we assume that the outer diameter was about 17° and that the cloud consisted of spherical droplets, we find from equation (1) that their diameter was 2.5×10^{-4}cm., approximately. For comparison it may be said that at the mountain Schneekoppe in Germany the smallest water droplets observed were 4×10^{-4} cm. in diameter. The horizontal velocity of these clouds is very variable. On December 30, 1926, Störmer observed mother-of-pearl clouds moving with a velocity of 75 m/sec. (167 miles per hr.) towards ESE, while on January 13, 1929, the velocity was too small to be determined. On this latter date the cloud fell 1.5 km. during 79 minutes (.31m. or 1 ft. per sec.), but another series of observations during the same day yielded a constant altitude of 23.8 km. Thus, there are evidently sometimes very strong vertical motions in these regions.

Störmer points out that the mother-of-pearl clouds were always observed on the west side of cyclones when the sky was clear due to Föhn effect. It is therefore possible that these high clouds are actually much more frequent than the few observations would indicate. But we can see them only if the sky is clearing for some reason, for example, due to Föhn effect at Oslo. From the little information we have to-day it is impossible to decide about their nature. It may be said, however, that at present there seems to be nothing which hinders us considering them as clouds consisting of condensation products of water vapour. Unfortunately, the humidity registrations made during sounding balloon ascents are rather unreliable and so we have no direct information about the moisture content at these levels. But, as figure 1 shows, the temperature up there is about -50°C. so that either super-cooled water droplets or ice crystals might exist without evaporating. The low temperature would not preclude the assumption of water droplets since supercooled water droplets at such low temperatures have actually been observed on arctic and antarctic expeditions.

Clearly to be distinguished from the mother-of-pearl clouds are

the ***noctilucent clouds*** which appear in the western sky after sunset, resembling cirrus or cirro-stratus clouds. The observations show that these clouds must be at very great heights since they are still in the direct sunlight when the sun is well below the horizon for an observer on the ground. The area of the illuminated part of the cloud consequently varies with the position of the sun. Their shape shows rapid changes. The colour is golden or reddish-orange near the horizon but, higher up, white or bluish-white. The few spectroscopic observations made on them do not reveal any emission lines. The spectrum resembles that of the sky during the day. Noctilucent clouds must consist of very tenuous material since the light from the stars suffers hardly any depletion in passing through them.

The most extensive determinations of height are due to Störmer who from observations in 1933 and 1934 found heights ranging from 80 km. to 90 km., with a mean of about 82 km. The highest velocity of these clouds which was observed is, according to an estimate by Jesse in 1888, 177m/sec. Störmer determined from more accurate observations on July 10-11, 1932, motions at the rate of 44-45 m/sec. from NNE, and on June 30, 1934, a current almost from E. to W. of more than 80 m/sec.

Vestine showed[7] that the noctilucent clouds have a yearly maximum of occurrence around July 10. The duration of twilight seems therefore to be only of secondary influence upon the frequency. The brilliancy of the clouds drops when the illuminating beam passes through the atmospheric levels below 30 km.

The origin of noctilucent clouds is still somewhat doubtful. Humphreys[8] suggested that they might consist of water droplets. He assumed a temperature lower than $-100°$C. at 80 km., a value which seems much too cold according to information from other sources. With a higher temperature, however, water could not exist in liquid form under the low pressure in the upper atmosphere.

Vestine[7] and Störmer[6] both favour a cosmic origin of the noctilucent clouds. Vestine gives a very suggestive graph showing that maxima of the frequency of noctilucent clouds always follow meteoric showers, while the relation to volcanic eruptions cannot be called satisfactory. In particular the occurrence of noctilucent clouds after the fall of the great Siberian meteor of 1908 is very conspicuous. Further, the appearance of the clouds mainly in June

and July, which might be compared with the preference of the meteors for certain fixed dates, could easily be explained by the assumption of an interplanetary origin. The blue-white colour would indicate that we have in these clouds dust particles rather than products of condensation. The absence of red light, incidentally, gives a hint as to the size of the particles. The particles should then, according to the theory of scattering, be comparable to the wave length of the red light (say 7.8×10^{-5}cm.).

While thus at present the evidence seems to indicate a cosmic rather than a terrestrial origin, it should be understood that this explanation cannot be regarded as final. The spectrum of the light of the night sky apparently contains the water vapour bands, so that there might very well be water vapour at the levels of the noctilucent clouds. The question of the temperature of these levels is not yet definitely settled and if the temperature should be much lower than we assume to-day, the water might possibly at times condense. It would be easier to explain the waves of 9 km. length and shorter which were observed by Störmer under the assumption that the noctilucent clouds are condensation phenomena. Then we should have to regard the clouds as stripes where upward motion of the wave takes place and the cloudless spaces as regions where the wave motion is downward. During the downward motion adiabatic heating and evaporation takes place, during the upward motion adiabatic cooling and condensation.

However, an explanation also seems possible on the basis of cosmic origin. We might, for instance, assume that we have a sudden change in wind distribution in the regions where noctilucent clouds occur. Then wave motions will be set up again, and either the crest or the trough of the waves might be under the influence of the more turbulent layer, thus blotting out those parts of the noctilucent clouds. The appearance of the wave structure during some displays of noctilucent clouds need therefore not to be taken as a serious obstacle to the theory of their cosmic origin.

III. Meteors

Lindemann and Dobson[9] pointed out that the height of disappearance of meteors shows distinct maxima of frequency, a

secondary one at about 45 km. and a primary one which lies roughly at 75 km. in winter and at 85 km. in summer. In fig. 2 the relation between the height of disappearance, velocity and frequency, according to Lindemann and Dobson's material, is represented. It will be seen that the height of disappearance is in

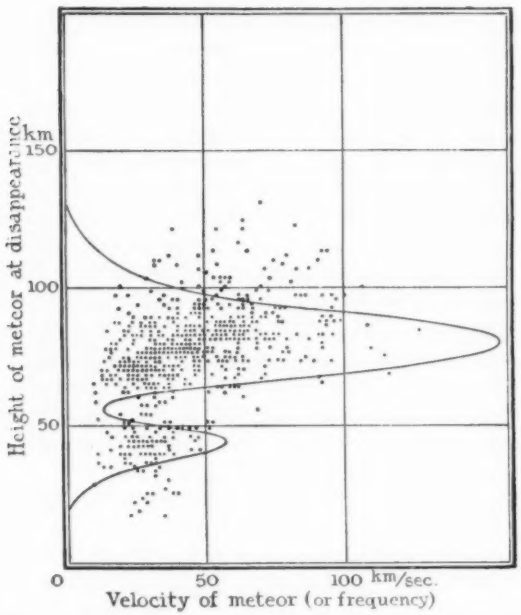

Fig. 2.—Height and velocity of meteors at disappearance, after Lindemann and Dobson (Proc. Roy. Soc. Lond. A, vol. 102).

general higher, the larger the velocity. Especially interesting is the drop in the frequency at 50-60 km. Similarly, A. Wegener[10] found two maxima for meteors brighter than Jupiter as shown by table I, only that now the lower is the main maximum. Furthermore, by grouping his material according to the velocities, Wegener

could show that for the velocity groups 0-10 km/sec. the mean height of disappearance is 28 km.; for the group 10-20 km/sec., 44 km.; for the groups 20-30, 30-40 and 40-50 km/sec., the height is the same, 47 km.; and it then rises to 55 km. for the group 50-60

TABLE I. Frequency of heights at which bright meteors disappear.

Ht. in Km.	0–10	10–20	20–30	30–40	40–50	50–60	60–70	70–80	80–90	90–100	100–110	>110
Frequency	6	20	73	120	97	63	43	44	39	17	8	11

km/sec. From this it seems that at 47 km., approximately, the structure of the atmosphere is such that meteors of very different velocities disappear. Similarly, the frequency drop at about 50 km. in fig. 2 seems to indicate that meteors which are able to intrude into the atmosphere down to roughly 65 km. can descend further to 50 km. where the resistance of the atmosphere becomes stronger again. We may therefore be justified in assuming a considerable change in the density of the atmosphere at this altitude. We shall see in the discussion of the anomalous propagation of sound that at these or somewhat lower levels the temperature of the atmosphere seems to be considerably higher than at the tropopause.

Egedal[11] has shown that a relation exists between the lunar atmospheric tides and the heights of disappearance and appearance of meteors. If these altitudes depend on the density of the atmosphere, it should be expected that at high tide both altitudes would be greater than at low tide. Since the phase angle of lunar tides counted in lunar time is generally smaller than ± 1 hour, Egedal grouped the observations according to lunar time t. The height h of appearance or disappearance should then be represented by

$$h = h_0 + l \cos 2t, \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where h_0 is the mean height and l the amplitude of the variation. From 142 observations made at Odder in Denmark the height of disappearance was given by

$$h_0 = 85.0 \pm 1.2 \text{ km.}$$
$$l = 5.5 \pm 1.9 \text{ km.}$$

From 504 bright meteors, the same material as used by A. Wegener[10], the height of appearance was given by

$$h_0 = 131.0 \pm 2.9 \text{ km.}$$
$$l = 10.8 \pm 4.0 \text{ km.}$$

The moonlight itself might influence these observations to some extent, but apart from that it seems that these figures show us directly the atmospheric tides in the upper atmosphere which at the earth's surface can only be found from the pressure observations after laborious calculations.

Meteor spectra are of course difficult to obtain. However, of the 23 spectra studied until now by Millman,[12,13] 14 were obtained from 1931-1933, showing that with a determined effort enough useful material can be collected. All these are bright line spectra with little or no continuous emission. According to Millman they can be divided into a type Y, where the H and K lines of ionized calcium are prominent, and a type Z, where almost all lines are due to iron, while ionized calcium is absent. One spectrum in which the magnesium line at 3830 A is stronger stands in a group by itself .For 8 meteors with known spectra the height was determined. Five of these, all with paths above 80 km., belonged to the type Y; the three other meteors, which appeared below 80 km., had spectra of the type Z. The assumption that the difference in spectral type is due to differences in the meteoric material, and that the Z type represents the irons, is rejected by Millman, since of 14 meteors 64% are of the Z type, while of the meteors with known data of fall only 5.4% are iron meteors. Besides, in the spectrum of the Z type there appear elements which are not found in the analysed iron meteors. Millman considers it more likely that the two types are caused by a difference in the degree of excitation or in the mechanism which causes the luminosity. We shall see that 80 km. is roughly the height of the lower ionized layer (Ch. V) and the minimum height of the aurorae (Ch. VII). It was mentioned that noctilucent clouds appear at this level. Thus at that height there is apparently an important boundary layer of the atmosphere. According to theoretical considerations by Maris[14] a gas cap will form at the front side of the meteor after it reaches levels below 80 km. At higher levels the light emitted by the meteor results from the

impacts between air molecules and meteor, below 80 km. the gas cap is the source of the light. The gas cap is formed in the lower levels since the mean free path is here smaller so that at 60 km. less than 1% of the molecules escaping the meteor would strike a molecule not in the meteor's path. While Maris's theory can hardly be regarded as final it seems certain that at 80 km. an important change takes place in the physical state of the meteor.

Millman has determined the effective temperature of some of the meteors from the intensity ratios of the Fe multiplets in their spectrum (table II). The temperatures corresponding to different ratios have been determined from laboratory experiments where

TABLE II. Effective temperature of meteors (after Millman)

Spectrum	Geocentric velocity	Effective Temperature	Height
XXIV	12 km/sec.	1770°-1910° K	67 km.
XIII	34	1810°	75
Perseid	56	2100°	..
Leonid	71	2700°	91
XIV	>100	3130°	104

equilibrium conditions prevail. One cannot assume that equilibrium exists also under the extreme condition when a meteor speeds through the earth's atmosphere. Thus the temperatures obtained by comparison with the laboratory experiments will not represent the actual temperatures. To indicate this they are called "effective" temperatures.

Unfortunately, there is no satisfactory theory of meteoric luminosity at the present time. Lindemann and Dobson[9] assume that luminosity starts when a gas cap is formed on the front of the meteor. This gas cap is heated by adiabatic compression and heats the meteor itself by conduction. The temperature of the gas cap can be estimated if it is assumed that the temperature of the meteor becomes so high that it will begin to vaporize. Then it is possible to conclude by working back what the temperature of the surrounding air may be. In this way Lindemann and Dobson arrive at temperatures of more than 25°C. at altitudes above 50 km. This

result is in agreement with other estimates of the temperature at these levels. But it must be stated, in spite of this, that the objections raised by Sparrow[15] and others against this theory have not been overcome. Sparrow points out that the law of adiabatic compression and heating can hardly hold if a body passes through the atmosphere with a velocity as high as that of a meteor. He assumes that the meteor is heated by direct impacts with air molecules. But Sparrow's assumption that the meteor radiates as a black body also seems untenable. Recently Öpik[16] has given the outlines of a new theory of meteors. He assumes that the luminosity arises chiefly from a vapour around the meteor, either as impact radiation (collision of air molecules and coma molecules) or temperature radiation (collision between coma molecules), and he discusses the dissipation of energy and generation of radiation in atomic collissions for velocities and elements most likely to occur in meteors. But his theory does not yet seem to be in a state where it is possible, from the meteor observations, to draw conclusions regarding the upper atmosphere. All theories so far have been developed without any knowledge about the meteor spectra. It is to be expected that the increase of this material will greatly clarify our ideas about meteoric theories.

The meteor trains indicate that even at these high altitudes the atmosphere is in a turbulent state. According to meteor observations[17] there are, in general, easterly winds over Europe and North America, of between 30 and 40 km., and prevailing westerlies above this level. The velocities in the upper level range from 30 to 80 m/sec. according to Olivier.

IV. The Light of the Night Sky

A statistical survey of the distribution of the stars over the sky shows that during a moonless night in parts of the sky with an average distribution of stars only three-tenths of the brightness can be due to the stellar illumination, if the scattering of the light by the atmosphere is taken into account.[18] This fact, together with the observation that the brightness of the sky increases with the zenith distance (outside of the Milky Way), suggests an atmos-

pheric origin of the remaining seven-tenths. The increase with increasing zenith distance is more marked for visible light than for the photographically effective radiation, indicating that the emission of light in the atmosphere is especially rich in yellow and green. Dufay[19] found a partial polarization of the light of the night sky (between 2 and 4%) with the plane of polarization always passing through the sun. The dependence of the degree of polarization on the angular distance from the sun resembles the behaviour of the polarization of the zodiacal light which, however, has a much larger degree of polarization. It seems therefore very likely that the polarized component of the nocturnal sky light is to be attributed to an extension of the zodiacal light over a large portion of the sky. Taking the brightness and the degree of polarization into account, it may be assumed that about 15% of the sky light is due to the zodiacal light.

The most prominent line in the spectrum of the night sky is a green line of 5577 A. It was first found in the auroral spectrum, then by Wiechert[20] in the spectrum of the clear night sky when no aurora was visible. Babcock[21] determined the wave-length with a Fabry-Perot interferometer and found $5577.351 \pm .005$ A. The line is single and not wider than .035 A. McLennan and different collaborators[22] produced the line in the laboratory by passing an electric current through a discharge tube with atomic oxygen. The intensity of the line increases with the addition of a rare gas. The line does not appear with the first discharge. It takes apparently some time before sufficient oxygen is transformed into a state in which the line can be emitted. The wave-length of the experimental line was determined to be $5577.341 \pm .004$ A, with a width of .030 A, in good agreement with Babcock's value. It is emitted by the metastable transition designated $2p^2D_2 - 2p^1S_0$. Under ordinary conditions on the earth's surface such states cannot be realized, but they are apparently possible under the conditions prevailing in the upper atmosphere. The influence of the rare gases in the laboratory experiments seems to take the place of the low density in the upper atmosphere.

The nitrogen bands 4278 A and 3914 A are much weaker in the spectrum of the night sky than the green line, while in the aurora all three lines are of approximately the same intensity,[24] as shown

by fig. 3. Kaplan [23] has produced a similar spectrum in the laboratory in a nitrogen tube containing traces of oxygen. The charge was rapidly interrupted so that the current did not reach the value which it would have in the steady state. The green line was particularly strong when the current was almost at the vanishing point.

Many other lines have been discovered in the spectrum of the light of the night sky. For a complete discussion the reader may refer to Déjardin's survey[18]. Only a few of the results are here mentioned. Besides the green line 5577 A two other forbidden lines of OI* appear

$$\lambda = 6300 \text{ A}(2p^3P_2 - 2p^1D_2) \text{ and } \lambda = 6363 \text{ A}(2p^3P_1 - 2p^1D_2)$$

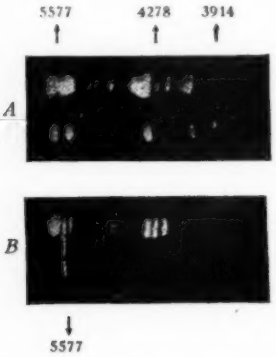

Fig. 3.—Spectrum of the aurora at Quebec (A) and of the light of the night sky at Lyons (B). After Dufay (Rev. Mod. Phys., vol. 8).

which together form the "red line" of the aurora[25]. Cabannes[26] found the telluric bands (vibration bands) of water vapour and of oxygen. There have been found other radiations which are interpreted as nitrogen bands. There seems to exist in the light of the night sky a continuous spectrum with Fraunhofer lines which forms a background for the other radiations.

*The Roman numeral I refers to the degree of ionization.

The intensity variations of the light of the night sky have been studied for a number of years by Lord Rayleigh and collaborators[27]. They used as a light source with which to compare the light of the night sky a preparation of double sulphate of uranyl and potassium. By the use of coloured filters the light of the night sky was analysed into a red, auroral (green) and blue region. To obtain a photometric balance neutral glasses of graded densities of .1, .2, .3, etc., were used. The scale of brightness employed represents an increase by one unit from one glass to the next. Observations were made at Terling, England, 1923-1934, Canberra, Australia, 1925-1934, and Cape Town, 1925-1933. The observations yielded an annual and semi-annual variation, the amplitudes of which are given in table III.

TABLE III. Amplitudes of annual and semi-annual variation of the light of the night sky

	Annual			Semi-annual		
	auroral	blue	red	auroral	blue	red
Terling	1.22	.69	1.15	.48	.09	.31
Canberra	.53	.20	.74	.52	.12	.25
Cape Town	.28	.13	.19	.33	.10	.19

The amplitude of the annual variation is evidently greater in higher latitudes. The ratios of the amplitudes for different spectral regions agree within the limits of error. The phase angles at Terling and Canberra would indicate that the yearly range of the intensity is opposite on the two hemispheres, but the phase angle at Cape Town does not fit in. The behaviour of the semi-annual variation is not very regular. The amplitudes for all three spectral regions are smallest at Cape Town and the amplitude is smallest for the blue region.

A slow general variation is superimposed upon these annual and semi-annual variations, and there seems to be a correlation with the amount of spotted area on the sun. The correlation coefficients range from +.89 for the blue region, over +.91 for the red to +.99 for the auroral region at Cape Town. But it would be premature

to put too much emphasis on these values since the Cape Town observations comprise less than a full sunspot period. At Terling and Canberra the correlation is only appreciable for the auroral region. The brightness seems to be a little higher on disturbed than on quiet magnetic days, but the relation is not pronounced. Irregular fluctuations are highest at Terling and lowest at the Cape, the mean absolute intensities are comparable but probably show the same trend. During short periods it was possible to obtain observations at many stations distributed over the globe[28]. The irregular variations noted were not correlated with each other.

A maximum in the brightness of the light of the night sky was found to occur around midnight according to Lord Rayleigh[29], and McLennan, McLeod and Ireton[30], while in India Karandikar[31] found a minimum between midnight and 2 a.m.

Cabannes and Dufay made an attempt to determine the height of the luminous layer of the nocturnal sky[32] from the ratio of the light intensity near the horizon to that near the zenith. The ratio is 1.5, from which value they conclude that the layer must be decidedly higher than 100 km., probably around 200 to 300 km.

The spectrum of the night sky shows that oxygen and nitrogen are present at the upper levels, but the absence of the lighter gases in the spectrum does not prove definitely their absence in the upper atmosphere. The state of the high layer might not be favourable for the emission of radiation from these gases.

Chapman[33] suggested the origin of the green line in connection with the reaction

$$2O = O_2$$

The energy may be stored up during the daytime when molecules are dissociated or ionized under the influence of short-wave solar radiation. The energy released by recombination is 6-7 volts, about twice the energy of excitation of the metastable atom. The emitting layer would then have to be placed between 100 and 160 km., since there are not a sufficient number of particles found at the heights determined by Cabannes and Dufay to account for the intensity of the light. This, however, would not be a serious objection since their determination can be considered only as a rough estimate.

(*To be continued*)

AMERICAN ASTRONOMICAL SOCIETY—CAMBRIDGE MEETING

By C. A. CHANT

THE fifty-sixth meeting of the American Astronomical Society was held at Harvard University on September 2-5, 1936. In celebration of the three hundredth anniversary of the founding of Harvard University a great Tercentenary Conference of Arts and Sciences was in session from August 31 to September 12 and the Society's meeting was organized as an integral part of it. The attendance at the meeting was exceptionally large, probably the greatest in the history of the Society.

On Wednesday, September 2, at 8 p.m. the Council was convened with a record number being present. President H. N. Russell was in the chair and in the absence through illness of the Secretary, Professor Dugan, Mr. John E. Merrill of Buffalo efficiently served in his place.

On Thursday at 9.30 was the first session for papers. On the printed programme there were 60 titles of papers and some 10 more were added. Of these, 30 were from Harvard Observatory. Notwithstanding this very large number, by reading together those relating to the same subject so that all could be discussed at the same time, and by strict adherence to the time schedule, the programme was carried out with marked success.

At 2.00 p.m. on Thursday two addresses of the Tercentenary Conference were given, namely, "The Temperature Scale of the Stars" by Antonie Pannekoek, and "The Masses of the Stars" by Henry Norris Russell.

At 4.30 p.m. Professor and Mrs. Shapley entertained at tea at the Observatory Residence. Rain had fallen earlier in the afternoon but the sky cleared and it was possible to meet on the lawn. Among the things to interest the visitors were various pieces of apparatus taken by the Harvard Expedition to Russia to observe the eclipse of July 18, 1936, together with some of the remarkable photographs obtained.

On Friday at 9.30 a.m. was another session for papers and all

those offered by Harvard Observatory were satisfactorily disposed of by 12.15 when the society photograph was taken. An excellent negative of an exceptionally large group of American astronomers was obtained. In the afternoon at 2.30 were two lectures on Cosmogony supplied by the Tercentenary Conference. The first was on "Astronomical Consequences of the Relativistic Problem of Several Bodies" by Tullio Levi-Civita, of the University of Rome; the second, on "The Cosmical Constant and the Recession of the Nebulae" was by Sir Arthur Eddington, of Cambridge University, England.

At 5 p.m. was a tea in the Fogg Art Museum by courtesy of Harvard University and at 7 p.m. about 200 members and their wives gathered in Lowell House for the society dinner. Following the meal some moving pictures of the solar prominences, taken very recently at the McMath-Hulburt division of the University of Michigan observatory, were exhibited with Director Curtis making comments. The dinner was a distinguished success.

On Saturday at 9.30 a.m. was the Annual Business Meeting at which it was stated that during the year 27 had been elected members and that Professor Kimura of Japan, well known for his investigations into the variation of latitude, had been elected an honorary member. The customary votes of thanks for entertainment and for services rendered were passed and also a resolution expressing the hope that Professor Dugan, the secretary, might speedily recover from his illness. Between 10 and 12.30 the remainder of the papers were read, and then the members started for the Oak Ridge Observatory, some 25 miles to the northwest from Cambridge by tortuous roads. In an hour it was reached and the neat and efficient mounting of the 60-inch reflector was admired by all. After a picnic bench in the fine surrounding grove the party dissolved. It was agreed that the meeting was a decided success. From Canada were Messrs. R. M. Stewart, Ralph E. DeLury, C. C. Smith, W. S. McClenahan, R. J. McDiarmid and M. M. Thomson from Ottawa; W. E. Harper from Victoria; H. R. Kingston from London; and L. Gilchrist and the present writer from the vicinity of Toronto.

THE NAMES OF ASTRONOMICAL OBJECTS

By E. G. Hogg*

The Stars and the Planets

MANY points of interest occur in connection with the names given to the various objects which are the subject matter of astronomy. The planetary bodies and their satellites get their designations from classical mythology; an Arabic origin can be ascribed to a fair proportion of the fixed stars which have proper names; lunar topography is for the most part described by the surnames of men of science; comets are now usually called after their discoverers, but those which appeared in past ages are distinguished by the year of their discovery; the naming of the asteroids is left to the discretion of those who detect them.

We may say that, except in the case of comets and lunar features, the practice of the past has been to avoid using for the title of a heavenly body, which is the possession of all mankind, the name of an individual, living or dead, but there are some cases when the rule has been violated to which a brief reference may be made. The great navigator Magellan has no claim to be the discoverer of the Magellanic Clouds—the Nubeculæ Major and Minor. They were well known before his day to the Dutch and other sailors as "The Great White Clouds"; but after his circumnavigation of the globe (1519-22) they became associated with the name of Magellan, and the title is still used. When Halley returned to England after his visit to St. Helena to observe the stars in the southern skies he showed that he was a courtier as well as an astronomer for, in gratitude to the monarch who had helped him in fitting out his expedition, he had carved from the adjacent constellations a new one which bore the name of "Charles' Oak." For some time this interloper held its place, but it never had a firm footing, and eventually disappeared from astronomical maps, though the brightest

* Prepared for the New Zealand Astronomical Society and Printed in the Christchurch *Press*.

star in this region is still known as "Cor Caroli." Another instance is Scutum Sobieski, a constellation formed in 1660 by Hevelius out of a part of Aquila, in honour of the Polish hero John Sobieski, but only the part Scutum is now retained in use.

The new planet which Herschel added to our system in 1781 he called Georgium Sidus, in recognition of the generous support he received from George the Third in his astronomical work. This name, however, gave offence, both at home and abroad, and the alternative title of Herschel was used for about half a century, when, by general consent, that of Uranus was adopted. Herschel's connexion with its discovery is, however, maintained by the fact that the planetary symbol of Uranus is a capital H, slightly modified. Coming to more recent days, it may be recalled that when a new planet was discovered in March, 1930, at the Percival Lowell observatory at Flagstaff, Arizona, the suggestion was made that is should be called Percival. Though this name was never seriously considered, the one eventually chosen—Pluto—was held to be specially suitable in that its first two letters were the initials of the man whose faith in the existence of a planet lying beyond Neptune had prompted the intensive search of the heavens which led to its discovery.

Perhaps the most curious effort ever made to associate a heavenly body with an individual was the proposal of the authorities of the University of Leipsic, after the defeat of the Prussian armies at Jena in 1806, that the constellation Orion should be known henceforth as "Napoleon's stars." The suggestion, however, was not well received, even in Germany, and we hear nothing more of it after the downfall of Napoleon.

One of the earliest discoveries made by Galileo with his telescope was that Jupiter was attended by four moons, and these he called the Medicean stars, in honour of a member of the Medici family, by whom he had been befriended and protected, and this title may be still met with in astronomical literature. For some time after their discovery by Galileo and Schreiner, sun-spots were regarded by some as small planetary bodies revolving about the sun; Tardé refers to them as Astra Borbonia, and C. Malapert called them Sydera Austricea, but these strange titles were dropped when the true nature of the spots was understood.

Asteroids

When the first asteroids were discovered, the practice was to name them after minor members of the classical mythology—Ceres, Pallas, Juno—but as their numbers increased difficulty was experienced in finding names from this source and new titles were invented. As a result some very uncouth designations have found their way into the list of asteroids and among recent discoveries we have Hanksya, Sakuntala, Moguntia, Scorria. On one occasion Dr. Palisa, of the Vienna Observatory, who for many years held pride of place as a discoverer of these objects, needing money badly for the uses of his observatory, offered to sell the privilege of naming an asteroid he had just discovered for £50. The offer hung fire for some time but eventually a member of the Rothschild family took it up and Bettina was added to the list. Feminine appellations are usually chosen for the minor planets, but a masculine name is often adopted for one of more than usual interest—as instances of this we have Eros and Amor—two asteroids whose motions bring them periodically into very close proximity to the earth and thus make them of remarkable value in the determination of the solar parallax. There are others connected by peculiar dynamical relations, which seem to point to some common feature in their origin; these are grouped in families such as the Trojan family, whose members are Hector, Achilles, Nestor, Priamus, and Patroclus.

Comets

As I have already said comets detected within recent years are in general named after the fortunate discover; when there is doubt on this point they are known by the year of their first appearance. As exception to this rule we may mention Halley's comet, which had made several apparitions before Halley studied its motions and identified it with comets which had been seen previously at intervals of 75 to 76 years. Its return the the neighbourhood of the sun he foretold in the memorable words, "If it should return, according to our predictions, about the year 1758, impartial posterity will not refuse to acknowledge that this was first discovered by an Englishman." The comet was first seen on Christmas Day, 1758, and

passed through perihelion on March 13, 1759! As a second instance may be cited Encke's comet, which has the shortest known period of revolution about the sun. It was discovered by Pons, of Marseilles, on November 26, 1818, but its motions were investigated by Encke, who showed that it was identical with one seen in 1786, 1795, and 1805, and the comet has since borne his name.

The Moon

We know by tradition and published records that from very early times the faint grey and light spots which diversify the face of our satellite excited the wonder and stimulated the curiosity of mankind, giving rise to suppositions more or less crude and erroneous as to their actual nature and significance. Anaxagoras, five centuries before our era, and probably other philosophers before him, taught that these delicate markings and differences of tint point to the existence of hills and valleys on her surface, and Plutarch maintained that the irregularities of outline presented by the "terminator" or line separating the illumined from the unillumined parts of the surface were due to mountains and their shadows, but more than 15 centuries elapsed before this sagacious conjecture was unquestionably demonstrated.

Selenography, as a branch of observational astronomy, dates from the time when Galileo directed his "optic tube" to the moon in 1609; in the following year, in his Sidereus Nuncius, he gave to an astonished and incredulous world an account of the unsuspected marvels his telescope had revealed. He conjectured that the grey, monotonous tracts were seas, while the bright, rugged areas were land, and in this view Kepler concurred. Langrenus and Hevelius appear to have been among the first to give distinctive names, mainly derived from terrestrial physical features, to the several formations visible on the lunar surface, but Riccioli, the Jesuit astronomer of Bologna, while retaining for the most part the names given to the maria or supposed seas, substituted for the titles of the mountain peaks, the names of philosophers, mathematicians, and other celebrities. He has been charged with showing some bias in his selection. Copernicus and Tycho designated two of the finest "craters" the moon possesses, but only a small ring-plain, nine

miles in diameter, honours the name of Galileo. Later selenographers have added their contributions, and in the lunar map you now encounter a curious jumble of ancient, medieval, and modern surnames. It is probably true to say that in many cases it is only their inclusion in this map that rescues them from oblivion.

It is interesting to speculate as to what would happen if through some planetary catastrophe the periods of the moon's rotation on its axis and its revolution about the earth ceased to agree, and that face of our satellite which no mortal eye has seen was slowly disclosed to our observation, and features hitherto unrevealed became visible to us. What committee could name these without offending the susceptibilities of the several nations seeking their place in the moon?

REVIEW OF PUBLICATIONS

Constellations, prepared by the Department of Astronomy of the Franklin Institute, Philadelphia. 32 pages, 6×9 inches, 1936. Price 35 cents.

This book has been prepared in connection with the Planetarium and Museum of the Franklin Institute, by Mr. James Stokley and his assistants. Its object is twofold. First, it is intended to provide visitors with a means of recalling some of the facts presented in lectures to them. For this purpose it contains 24 simple star maps, showing the sky looking north and looking south each month; a description of the Planetarium; some astronomical tables; and a list of books for further reading. Then it is thought that the publication should be of interest to a larger public. The knowledge of astronomy is certainly spreading rapidly and this little book will accelerate the motion.

It is stated that the cost of a Planetarium is 315,00 RM, or $127,500 at the present rate of exchange. I presume this includes the projecting instrument and the dome, which must be of a special construction.

C. A. C.

METEOR NEWS

Observations relating to meteors and meteorites are cordially invited.

The Frequency Distribution of the Time Intervals Between Meteors

During the past five years a large amount of observational material has been accumulated in visual meteor programmes conducted by the writer, first at the Harvard Observatory and more recently at the Dunlap Observatory and associated stations. Since in all cases the meteors were timed to the nearest second it was thought worthwhile to analyse the frequency distribution of the time intervals between successive meteors.

Let us assume that all meteors visible from a station represent those occupying a certain cylinder of space and that these have a perfectly random distribution. Let N meteors be observed in an observation period of S seconds. Then we may define the mean interval between meteors as $S/N=T$ seconds.

The probability of seeing a meteor in time dt is dt/T

" " " " no meteor " " dt " $1-dt/T$

Let $F(t)$ be the " " " " " " " " t

The " " " " " " " " $t+dt$ is $F\times(1-dt/T)$

which also equals $F+F'dt$.;

Therefore $F'dt=-Fdt/T$

F $=\text{const.}\times e^{-t/T}$

But if $t=0$, then $F=1$.

Therefore $F=e^{-t/T}$

The probability of seeing no meteor in time t and then a meteor in time dt is $e^{-t/T}\times dt/T$.

Therefore the probability of an interval in the range t_1 to t_2

$$\text{is } \int_{t_1}^{t_2} e^{-t/T}dt/T=e^{-t_1/T}-e^{-t_2/T}.$$

The observations were divided into periods over which T did not vary greatly and the number of intervals from $0.0T$ to $0.1T$, $0.1T$ to $0.2T$, $0.2T$ to $0.3T$, etc., were tabulated. These results, derived from various values of T, were then summed and the

totals reduced to fractions of the total number of intervals. The resulting frequency diagrams are illustrated in Figure 1.

The observations utilized in this analysis were made during the annual appearances of the Perseid and Leonid meteors. In

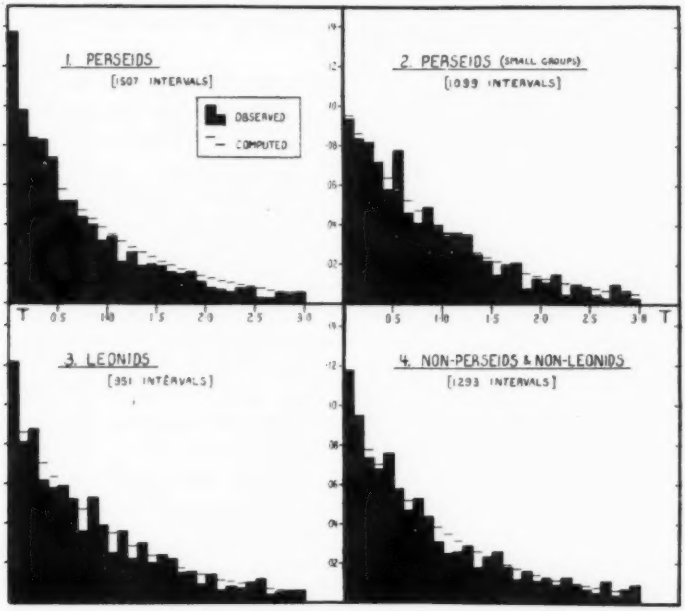

FIG. 1.—THE FREQUENCY OF INTERVALS BETWEEN SUCCESSIVE METEORS PLOTTED AGAINST THE MEAN INTERVAL T.

1. *Perseids*—Dunlap Obs. 1934, 1935. T varied from 35 to 230. Average $T=85$. Average number of observers = 8.
2. *Perseids (small groups)*—Stations in Ont. and Que. 1934, 1935. T varied from 50 to 400. Average $T=115$. Average number of observers = 4.
3. *Leonids*—Harvard Obs. 1932; Dunlap Obs. 1933, 1934, 1935. T varied from 50 to 300. Average $T=125$. Average number of observers = 11.
4. *Non-Perseids and Non-Leonids*—1932 to 1935. T varied from 60 to 800. Average $T=250$. Average number of observers = 9.

general a fairly large group of observers co-operated at each station as under these circumstances there was less chance of some meteors being missed. Since the majority of meteors observed were plotted, meteors occurring in rapid succession would be the

most likely to be omitted. Any errors of this kind would tend to make the observed frequency distribution less rich in very short intervals than the true distribution. Where there were several recorders at one station care was taken that each meteor was counted only once in the reduction. Leonids and Perseids were separated from the meteors not belonging to these showers and the three groups treated separately.

It will be seen from the Figure that in all cases, except that of the Perseids observed by small groups, more of the smallest intervals were observed than would be expected by a theory of random distribution. This divergence from the computed values is particularly marked in the case of the Perseids observed at the Dunlap Observatory. The question now arises as to whether this excess of very small intervals is real or is merely due to accidental variation from a theoretical mean.

The natural uncertainty of a counted number N is $\sqrt{N}$. If the above frequency distributions were formed from observations with a uniform T, then the natural uncertainty of each column could be computed directly from the above definition. Since, however, T varied considerably, the natural uncertainty will be somewhat different from $\sqrt{N}$, though this value can be taken as a first approximation. In deciding whether the excess of small intervals is real or not it will be instructive to consider the ratio of the deviation of the observed from the computed frequencies, O−C, to the approximate natural uncertainty $\sqrt{N}$. This function, $(O-C)/\sqrt{N}$, was computed for the first twenty intervals in the frequency diagrams and will be found in Table 1.

In a discussion of this table it should be remembered that the results near the top of the table depend on a much larger number of counted intervals than those near the bottom. Hence, one should really think of the mean of two or three values when considering the lower part of the table. Taking the Perseids observed at the Dunlap Observatory it will be seen that from $T=0.0$ to $T=0.5$ the deviations are all positive while after this they are all negative or zero. The mean deviation for the first five intervals is 2.0 times the natural uncertainty while that for the first interval is 4.4. times the natural uncertainty. In contrast, the deviations of the next 15 intervals average 0.9 times the natural uncertainty and

since they are all negative the average scatter about their own mean is considerably less than this. In view of this marked excess in the first five columns of the frequency diagram it would be more correct to fit the theoretical curve to the range $T=0.5$ to $T=3.0$ rather than to the whole diagram. If this is done the ordinates for the theoretical curve must be reduced by 15 per cent. This of course renders the excess in the first five columns still more marked. With the revised theoretical curve intervals from $T=0$ to $T=0.1$ are 1.69 times as numerous as given by the computed

TABLE 1

THE RATIO OF THE OBSERVED DEVIATION TO THE NATURAL UNCERTAINTY

	Perseids	Perseids (small groups)	Leonids	Non-Perseids and Non-Leonids
0.0–0.1 T	+4.4	− .1	+2.4	+2.4
0.1–0.2	+1.5	− .2	− .5	+1.1
0.2–0.3	+ .8	+ .5	+1.0	− .5
0.3–0.4	+1.8	+ .1	−1.0	− .3
0.4–0.5	+1.4	− .8	− .8	+1.6
0.5–0.6	−1.0	+2.4	+ .1	.0
0.6–0.7	.0	− .9	.0	− .8
0.7–0.8	− .6	−1.0	−1.8	+ .9
0.8–0.9	− .5	+ .9	+1.3	+ .3
0.9–1.0	−1.5	+ .2	.0	−1.6
1.0–1.1	.0	+ .2	−1.7	−2.0
1.1–1.2	−3.0	+ .7	+ .6	−1.3
1.2–1.3	− .7	+1.1	−1.3	.0
1.3–1.4	−2.0	− .2	+ .7	−2.1
1.4–1.5	− .8	− .2	− .6	.0
1.5–1.6	− .6	−1.6	+ .6	+1.1
1.6–1.7	− .9	+ .2	+ .6	− .3
1.7–1.8	− .6	+ .9	− .5	−1.7
1.8–1.9	.0	−2.6	− .2	.0
1.9–2.0	−1.1	− .3	−1.6	−1.0

curve and intervals from $T=0$ to $T=0.5$ are 1.42 times as numerous. The resulting average excess of intervals in the first five columns is 3.6 times the natural uncertainty. It would seem in this case hardly possible to ascribe the observed deviations to accidental errors, especially as the chief cause of inaccuracy (*i.e.*, that of failing to record certain meteors), tends to decrease the relative number of small intervals. This last named effect is seen in the

values derived from the much less homogeneous material resulting from the Perseid observations by small groups. The excess of small intervals is here lacking.

In the case of the Leonids and the Non-Perseid-Non-Leonid groups the results are much less conclusive. The first interval in each case has a positive deviation of 2.4 times the natural uncertainty which is greater than any other deviation. The mean of the absolute values of the deviations for the following 19 intervals is 0.8 for the Leonids and 0.9 for the Non-Perseid-Non-Leonids. In both these cases there is then a tendency to excess of small intervals, but a definite conclusion should be reserved till further observational data can be examined.

The above results would seem to indicate that the Perseid meteors show a higher organization than either the Leonids or the other meteors appearing at the same time.

The writer would like to express his thanks to Prof. C. Barnes in the Department of Physics at the University of Toronto for his assistance with the theory contained in the above discussion. The writer would also like to acknowledge with thanks the work of reduction from the original records performed by Mr. Murray D. Stewart, student in the school of Applied Science, and by Miss M. E. B. McKinley, Mr. D. A. MacRae, Mr. D. B. Scott and Mr. Aubrey White, members of the Mathematics and Physics course at the University of Toronto.

P. M. M.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

A Ribbon-like Auroral Display

During the summer the Editor received from Mr. H. Boyd Brydon, of Victoria, B.C., a description of a very peculiar auroral display which he had observed from 10 to 11 p.m. on the evening of June 17, 1936. Mr. Brydon sent a circular star map on which the narrow strip of the sky covered by the aurora is marked. It runs through Aquila, Ophiuchus, Serpens, Boötes, Virgo and into Leo, reaching almost to Regulus. There was also some auroral illumination in the north over Andromeda, Cassiopeia and Perseus.

At 22.2 the ribbon-like arc was about 4° wide, slightly narrower perhaps directly south, and extending quite uniformly across the sky from about 10° above the horizon in the ESE to near the horizon on the WNW. Colour reddish. Intensity of glow about uniform throughout its length. No movement. At first glance it was similar to a narrow searchlight beam, but the edges were not quite straight. The sky was clear of cloud and stars of mag. 4 were easily seen.

At 22.25 auroral light was seen in the north as described above. This gradually increased in intensity.

At 22.3 a rift appeared in the narrow arc in Ophiuchus.

At 22.4 the portion west of Arcturus was distinctly fainter and the rift was growing in length and width. South of the rift the auroral illumination grew brighter and about this time pulsations were noticed moving westward along the arc in Ophiuchus like balls or ovals of luminous smoke about 2½° to 3° in diameter, bright against a much fainter background. They appeared near Alpha and Beta Ophiuchi and travelled in about 6 to 7 seconds from Alpha Serpentis to Alpha Boötis, where they disappeared.

By 22.7 the ribbon-arc had nearly disappeared except for three and again four stationary streaks over an arc about 8° long running north and south near Alpha and Beta Ophiuchi. These streak were about 1° wide, 4° to 6° long and about 2° apart.

By 22.9 the southern luminosity had nearly disappeared, some faint areas above remaining. Meanwhile the northern aurora had brightened but no conspicuous features were seen here.

Mr. Brydon later drew attention to an account by Frank C. Jordan in *Popular Astronomy*, vol. 24, p. 401, 1916, of a similar aurora observed at Pittsburgh on Friday, April 28, 1916. The present writer recalls seeing a precisely similar display but cannot find his record of it. It was probably the one described by Dr. Jordan.

THE OBSERVATORY OF SAN MIGUEL

On December 12, 1935, the observatory of San Miguel in the Argentine Republic was formally opened. It is located about 30 km. from Buenos Aires. Although it belongs to the Jesuit Society the new observatory is officially connected with the National Council of Observatories. It is patterned after the Observatory of the Ebro at Tortosa, Spain, which for the last thirty years has ceaselessly made observations on cosmical physics and in spite of many difficulties has kept its publications up to date. The observatory of San Miguel will study the influence of the sun, and in general the "cosmos", on terrestrial phenomena. The first work being undertaken is, in addition to the ordinary phenomena of meteorology, the recording of the electric potential of the atmosphere, of the ionization of the air, and of earth currents. The observatory is also endeavouring to popularize the study of science and along with the technical publications a number of "popular" brochures have been issued (in Spanish). The director is Ignacio Puig, S.J., and it is hoped that he and his observatory may be able to carry on their careful labours undisturbed for many years. In the course of time these long-continued observations will provide the solution to some of the riddles confronting the modern meteorologist.

A VERY USEFUL CATALOGUE

As further evidence of the importance of spectrum analysis in physics and astrophysics at the present time reference may be made to the catalogue of "Instruments for Spectrographic Analysis" by Bausch and Lomb, Rochester, N.Y., first issued in 1932 and revised and reprinted in 1936. It contains much valuable and interesting material.

First is a brief account of the theory and principles of design of the spectrograph, in which is concisely explained the meaning of dispersion, resolving power and purity. Then follow some illustrated examples of the application of the method to metallurgy and biology, which show the way to obtain precise quantitative results. After this some fine instruments are described, and at the end is a list of 68 of the most useful publications on the subject. The pamphlet runs to 32 pages and is beautifully produced.

C. A. C.

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